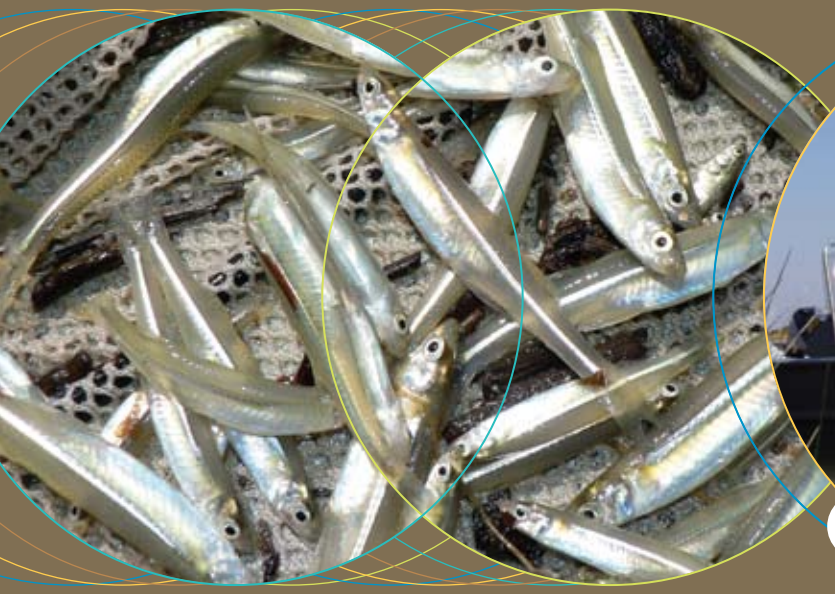
The Fish Mercury Project

The UC Davis Biosentinel Mercury Program

Using Small Fish to Monitor Fine-scale Patterns of Methylmercury Contamination in the Watershed



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THIS FACT SHEET presents highlights from the Fish Mercury Project on the subject of biosentinel small fish mercury monitoring, a tool that has great value in informing environmental managers of the impacts of their projects on mercury accumulation in the food web. The work is a part of the Fish Mercury Project, a study funded by CALFED that is the most comprehensive assessment to date on mercury contamination of fish in the Bay-Delta watershed and a ground-breaking effort to reduce mercury exposure through communicating safe eating guidelines to people who enjoy consuming fish from the Delta region. The Project, which began in 2004 and will be completed in 2008, includes the most extensive application of biosentinel mercury monitoring ever conducted in the western United States, providing information to help watershed managers better understand and reduce the movement of toxic methylmercury into fish. A full report on the Fish Mercury Project is available from the Project website: www.sfei.org/cmr/fishmercury. The biosentinel portion of that report can be found on pages 64-75. In addition, an extensive technical report specifically addressing the biosentinel work is available at www.sfei.org/cmr/fishmercury/DocumentsPage.htm or upon request from Darell Slotton at UC Davis: dgslotton@ucdavis.edu.

FACT SHEET

Tracking Methylmercury Exposure

Why Biosentinels?

The UC Davis research team uses small, young-of-the-year fish as its primary mercury monitoring tool, based on over 20 years of refinement of this approach. These localized and short-lived little fish are a key element of CALFED's Mercury Strategy and are referred to as **mercury biosentinels**. The small biosentinels complement sport fish and human health monitoring by providing **a sensitive measure of methylmercury exposure to the aquatic food web**. "Methylmercury" refers to that key fraction of mercury that has been converted to toxic methylmercury, made its way through complex production and loss cycles in the sediments and water, and is actively moving into the aquatic food web. Biosentinels can provide detailed information about varying levels of methylmercury exposure for fish, both geographically and over time. In other words, **biosentinels help to answer the "where" and "when" questions of how methylmercury gets into fish and the rest of the food web**.

The amount of mercury in adult sport fish (fish caught for recreational or subsistence purposes) is a result of the methylmercury taken up throughout their multi-year lives and throughout the potentially varied locations where they have lived. By virtue of the young age and small home ranges of small biosentinel species, the timing and location of their mercury exposure can be much more precisely pinpointed.

An Ideal Feedback Tool for Watershed Managers

A major focus of the biosentinel monitoring is to track and provide feedback on the potential effects various wetland restoration projects may have on methylmercury exposure, both locally and regionally. Certain wetland environments have been shown to provide ideal conditions for the production of methylmercury, often resulting in increased concentrations in fish. As large new wetland restorations are implemented in the Bay-Delta, there is concern that they may result in elevated exposure, both locally and regionally. Biosentinel monitoring provides quick and detailed feedback on how exposure levels may change in relation to these developments. **Biosentinel monitoring is a powerful tool to identify the management practices and natural processes that result in higher or lower levels of methylmercury uptake by fish**.

Biosentinel fish can differentiate methylmercury exposure conditions between adjacent wetland tracts or neighboring tributaries. Other important uses of biosentinel monitoring are the identification and ranking of mercury sources in contaminated watersheds and the tracking of cleanup effectiveness at remediation sites such as abandoned mercury mines.

The current Fish Mercury Project (FMP) biosentinel monitoring is **based on 20 years of method development and refinement** by the Slotton laboratory at UC Davis, in dozens of projects conducted throughout the state and beyond. The research group employs an integrative approach, from sampling design through field collections, sample processing, in-house laboratory analyses, data work up, and interpretation. Previous regional studies by the group (including two funded by CALFED) have demonstrated that mercury levels in biosentinel organisms are closely linked to methylmercury concentrations in water, as well as to sport fish mercury. **They provide a dynamic and direct measure of exposure to the food web**. They also represent mercury levels in the prey items of both sport fish and fish-eating wildlife.

Accurate Measure of Change Over Time

Because the biosentinels used are typically young-of-year fish, samples from one year to the next are, by definition, entirely different crops of fish, each exposed solely to conditions of the year sampled. **They thus provide quick and significant feedback to watershed managers if exposure conditions change from year to year.** At index sites across the watershed, this annual information contributes to an invaluable long-term record of fluctuating methylmercury exposure conditions that can be linked to natural and managed processes. In addition to assessing long-term trends, annual data can also provide a measure of natural, year-to-year variability at index sites, which should be taken into account when assessing trends at restoration and remediation sites. Finally, the short life spans of these little fish cause them to also register exposure changes from one season to the next, **allowing us to determine if and when methylmercury exposure may change during the course of a year**. Seasonal fluctuations in exposure to fish were in fact found, in the most recent work, to be far more important than anticipated.

Major New Finding: The Importance of Episodic Flooding

Extensive seasonal studies were conducted in conjunction with the large flooding that occurred in the watershed in 2006. Some areas received flooding that came in the form of winter rain-runoff. Others experienced flooding later in the spring and early summer, linked to snowmelt. Still others had man-made seasonal flooding due to management practices. All of these conditions were **found to lead to significant increases in methylmercury exposure to fish, and some highly elevated small fish mercury concentrations**.

The San Joaquin and Cosumnes Rivers experienced heavy flooding in 2006 in conjunction with spring snowmelt. Extreme (400-500%) increases in small fish mercury were found at these two sites by July *(page 5)*. Concentrations in 2-3 inch fish reached levels averaging 243 ppb at Vernalis and an astounding 869 ppb in the Cosumnes River, with individual, very small fish as high as 2000 ppb. **These were concentrations of serious concern**, particularly in relation to wildlife exposure. Quickly growing, rapidly regenerating species subsequently returned to lower levels, while other species remained highly elevated for up to a year.

The flooding-related increases in exposure measured with the biosentinels in several diverse habitats closely corresponded to results from water sampling by other researchers, which found elevated methylmercury in water at some of the same locations and dates. **What these sites had in common was episodic flooding of normally dry valley soils**. Follow-up monitoring in 2007, which was a relatively dry year with little or no flooding, confirmed the relationship: small fish biosentinels exhibited no increases during the same times of year that had shown the dramatic increases in conjunction with flooding *(page 5)*.

Valuable Information for Managers

With the 2005-2007 Fish Mercury Project, the UC Davis Biosentinel Program has developed an effective monitoring network across the watershed and has identified:

- broad and fine-scale geographic trends in fish exposure to methylmercury;
- seasonal spikes in exposure; and
- significant changes between years.

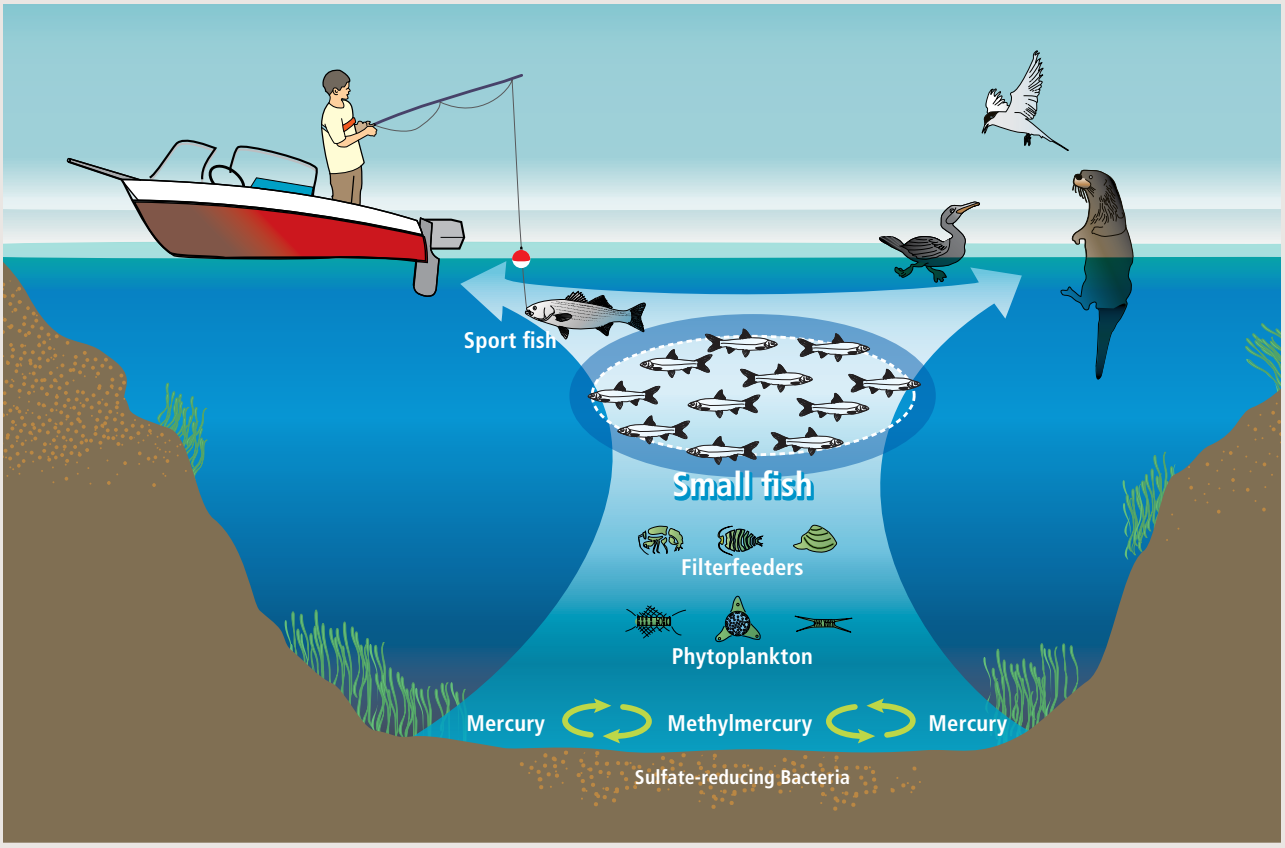
This program has demonstrated that biosentinel monitoring provides targeted, fish-based feedback that is essential to managing wetlands and other aquatic habitats more effectively for mercury.

From Planning to Monitoring to Management

Problem Definition and Planning | Field Sampling | Small Fish | Sample Preparation | Laboratory Analyses | Data Workup & Interpretation

The Biosentinel Mercury Program designs sampling in conjunction with specific management questions as well as for broader, regional coverage. Targeted small fish species are collected using a wide array of techniques and are carefully preserved in the field. Samples are weighed, measured, dried, and powdered prior to analysis. Laboratory analyses for mercury and related parameters are conducted by Program personnel, as is data analysis and interpretation. This feedback is then given to watershed managers to help track conditions and refine management strategies for mercury.

Mercury Movement into Small Fish and Up the Human and Wildlife Food Chains



Mercury exists in many different forms in the aquatic environment. *Methylmercury is the form of primary concern because it is readily accumulated in the food web and poses a toxicological threat to highly exposed species. Mercury from historic mining districts and other sources is converted to methylmercury principally by bacteria in sediments of aquatic ecosystems, especially near the boundary layer between oxygenated and non-oxygenated conditions. Methylmercury reaches higher concentrations with each step up the food chain – from water, to phytoplankton, to filter feeders, to small fish, to sport fish and humans or to wildlife – in a process known as "biomagnification." Concentrations in large predatory fish and fish-eating wildlife end up being about 5 million times higher than in water. There are complex production and loss cycles for methylmercury in the sediments and water. Small fish biosentinels are an ideal link to monitor, as they quantify methyl-mercury after it has been clearly incorporated into the food web. The small fish provide sensitive measures of the location and timing of net methylmercury exposure for both the sport fish and wildlife pathways.*

Some of the Primary Biosentinel Species of the Bay-Delta Watershed

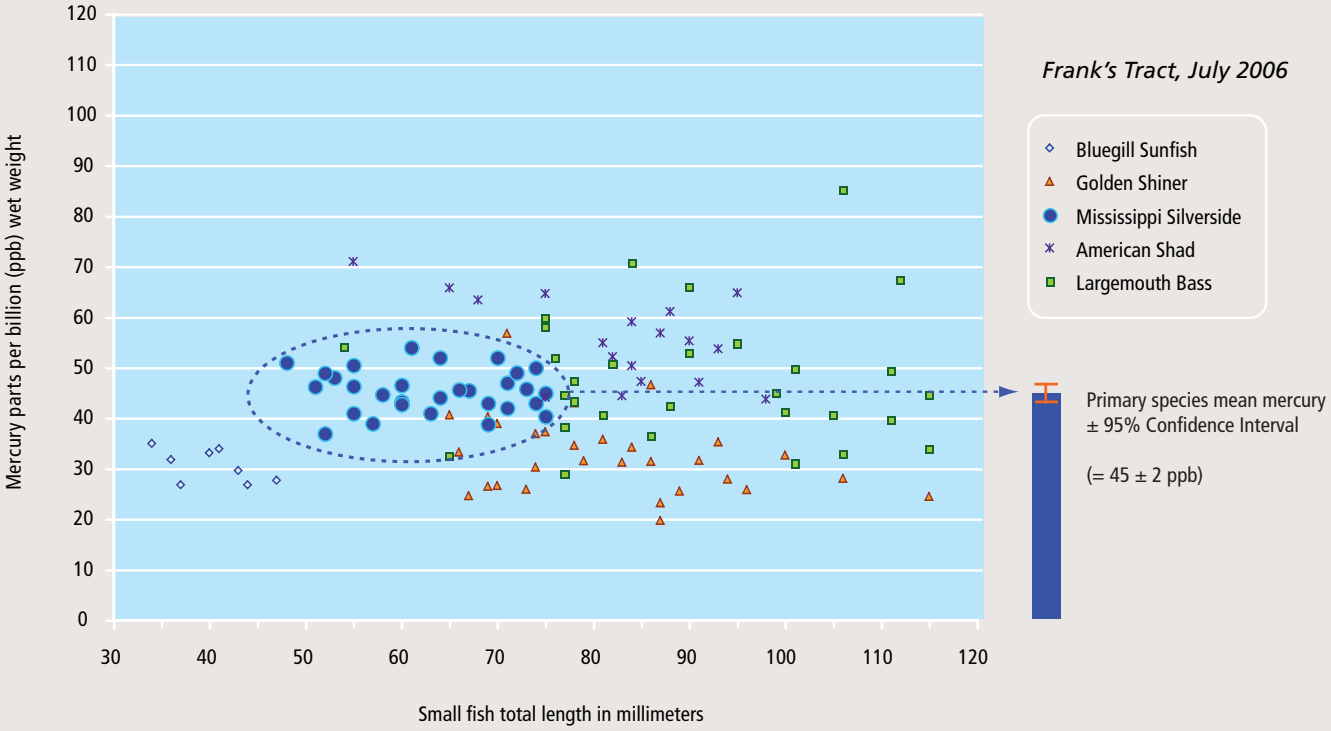
Prickly Sculpin

Mississippi Silverside

Juvenile
Largemouth Bass

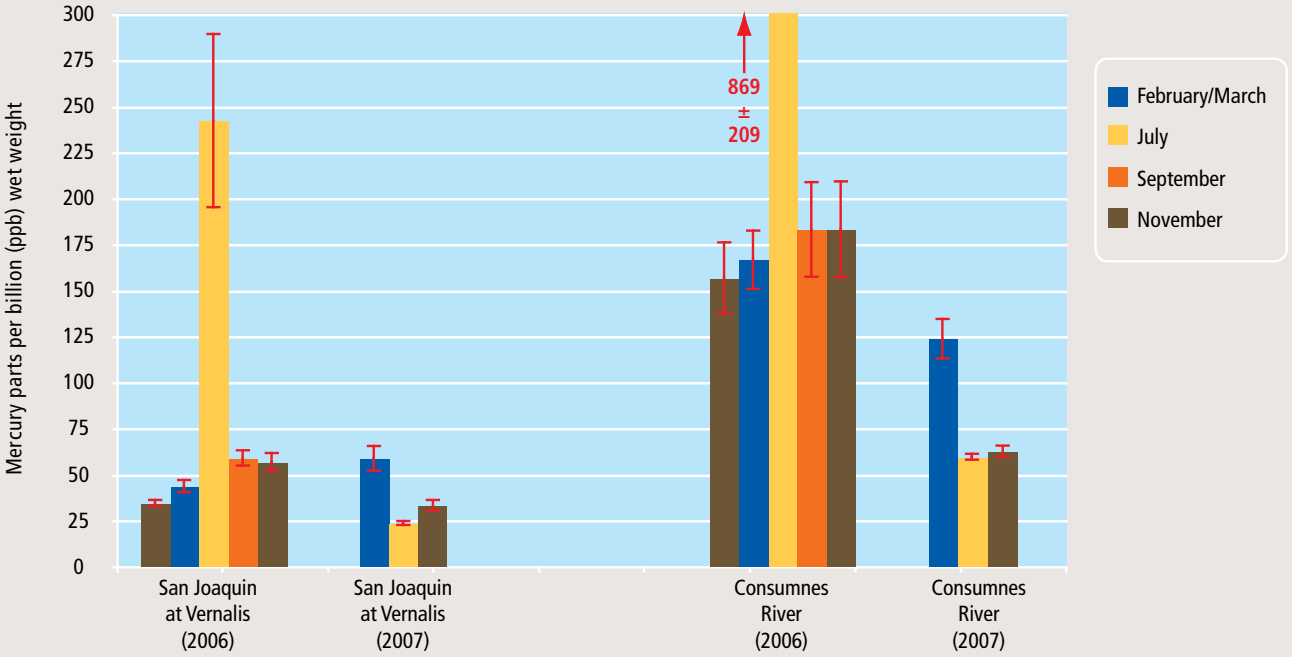
Different species have been identified to best answer different types of exposure questions across the range of aquatic habitats throughout the watershed. Ideal size ranges, collection strategies, and interpretive protocols have been developed for each.

Multiple Individual Biosentinel Sampling Approach



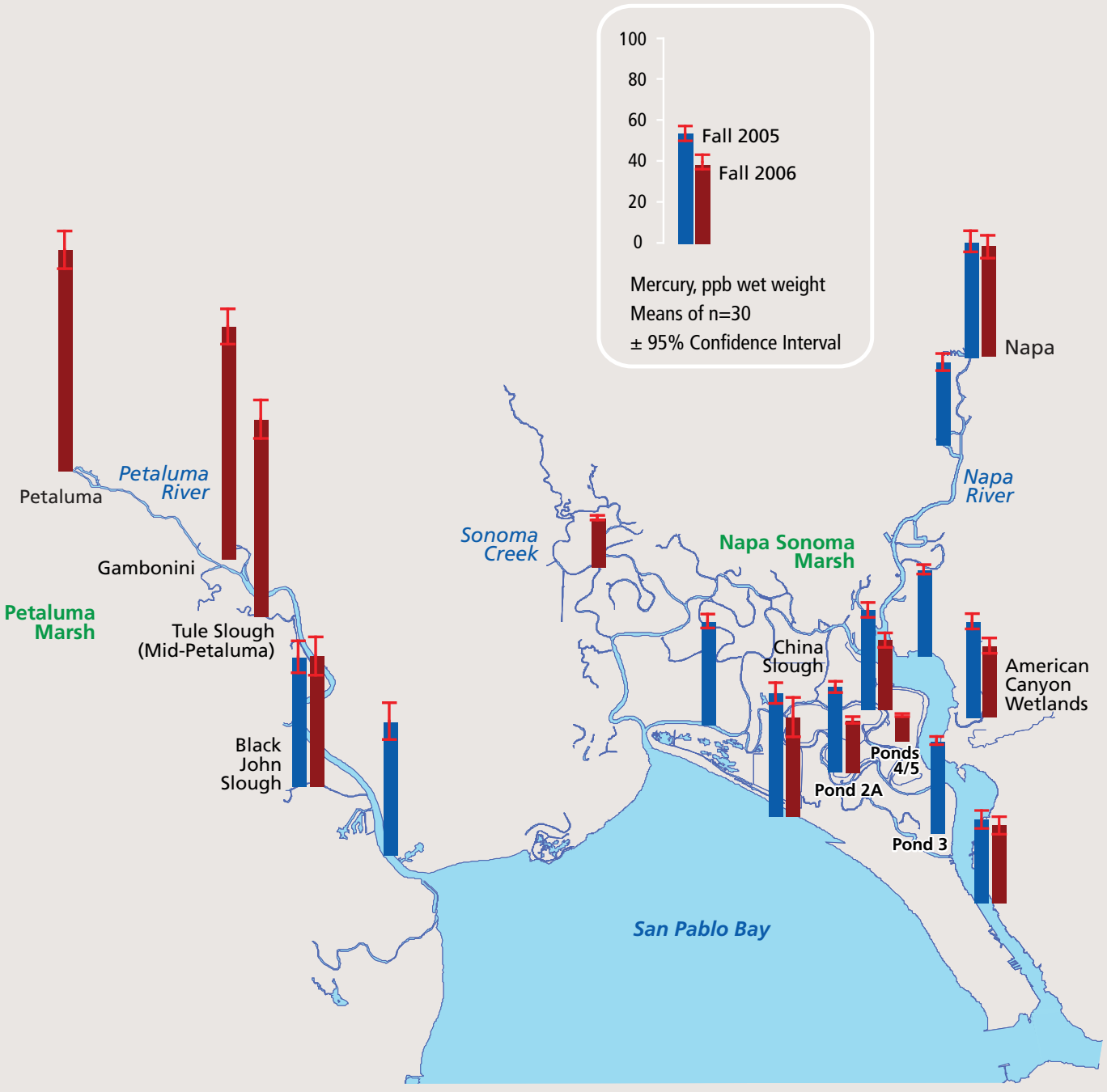
Mercury concentrations versus fish size from a single site-sampling event; primary species in large, blue symbols. Thirty very similar individuals of the primary species are collected and analyzed, leading to strong statistics for each collection that can be compared to other sites and times.

Strong Seasonal Trends Identified, Linked to Flooding Events



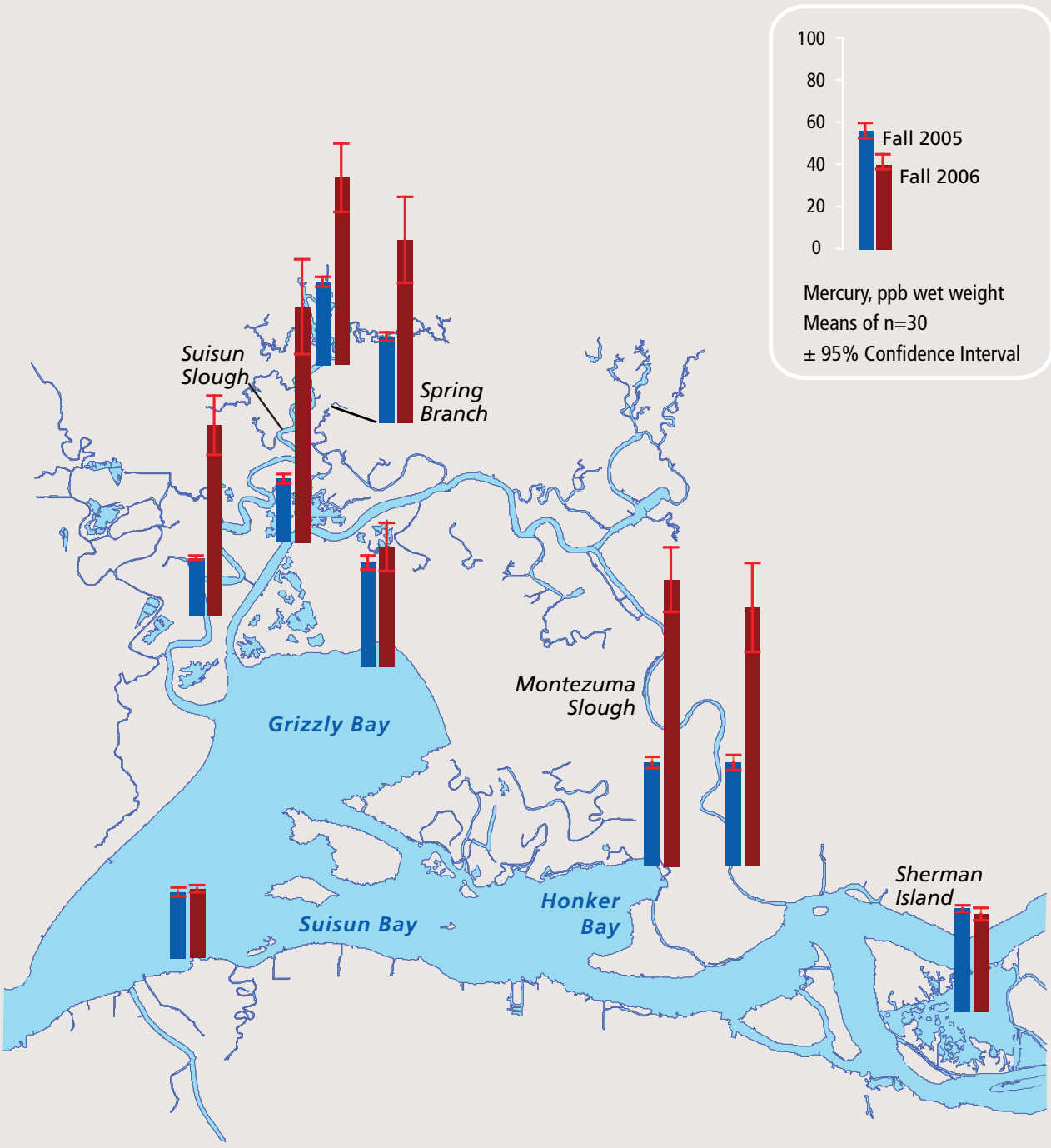
Historically high spring snowmelt runoff and flooding in 2006 was followed by large summer increases in small fish mercury downstream on the San Joaquin and Cosumnes Rivers. In contrast, 2007 was a non-flooding year and biosentinel fish responded with dramatic reductions in mercury bioaccumulation. Episodic flooding of usually dry soils has been implicated, through the biosentinel work, to be a primary factor leading to elevated methylmercury in the food web. This effect has been found in the summer at sites flooded by snowmelt runoff, in the winter and spring at sites flooded by rain runoff, and throughout the year in relation to man-made seasonal flooding conducted for management practices.

Surprisingly Low Mercury in Biosentinels Near North Bay Restoration Projects



Biosentinel monitoring found the Napa-Sonoma Marsh (see Back Cover for location) to contain lower fish mercury than adjacent aquatic habitats. This is notable, as the Napa-Sonoma Marsh is the site of some of the most extensive new wetland restoration work in the watershed and this restoration is not resulting in elevations in fish mercury at this time. Petaluma Marsh, in contrast, was identified as a zone of clearly elevated exposure, possibly linked to episodic tidal flooding of the extensive high marsh characteristic of that area.

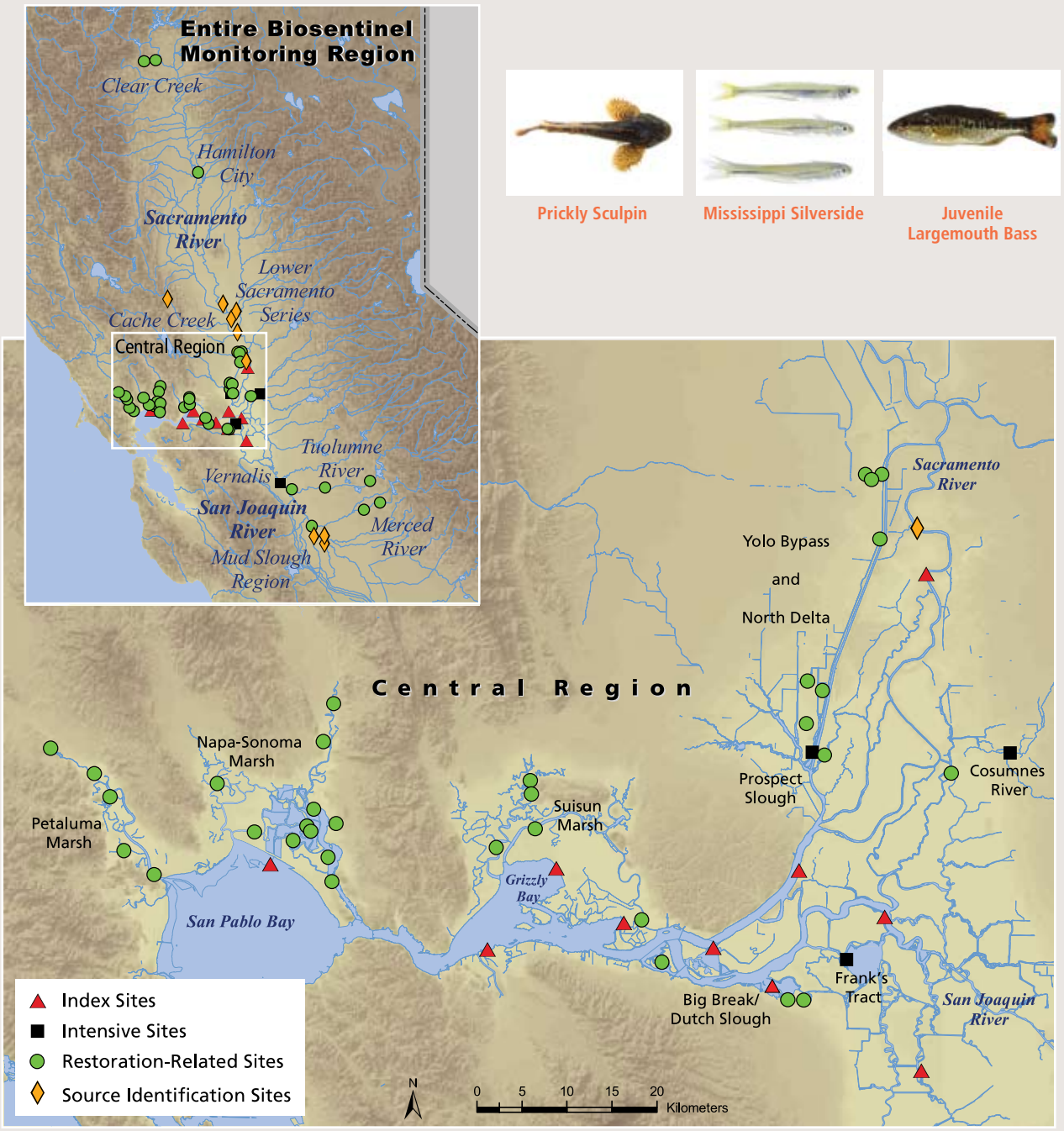
Suisun Marsh Identified as a 2006 Watershed "Hot Spot"



Annual sampling found large increases in biosentinel mercury in Suisun Marsh in 2006 (see Back Cover for location), while control sites outside the marsh remained unchanged from 2005. Possible causes are under investigation. These data demonstrate the utility of the small fish biosentinel approach to clearly and statistically differentiate methylmercury exposure among nearby locations and between years.

Exhibit 2: Fact Sheet on Biosentinel Mercury Monitoring

Biosentinel Sampling Locations, 2005-2007



Prickly Sculpin

Mississippi Silverside

Juvenile Largemouth Bass

Approximately 50 sites have been sampled each fall, with approximately 20 of these also tracked seasonally. *Over 3,000 individual small fish have been carefully collected and analyzed in each year of the Fish Mercury Project, the largest application of these techniques to date in the western United States. The majority of sites have been distributed in and around major wetland restoration areas. Index sites track regional trends and provide background data for interpreting restoration monitoring. At Intensive sites, mercury bioaccumulation relationships among different biosentinel species have been examined in greater detail and with more extensive sampling. The biosentinel approach is also ideal for source identification; Source Identification sites have been added as needed to help pinpoint the origins of elevated methylmercury signals.*

Credits and Acknowledgments

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